# FU19 *Nephrops* grounds 2019 UWTV survey report and catch scenarios for 2020.

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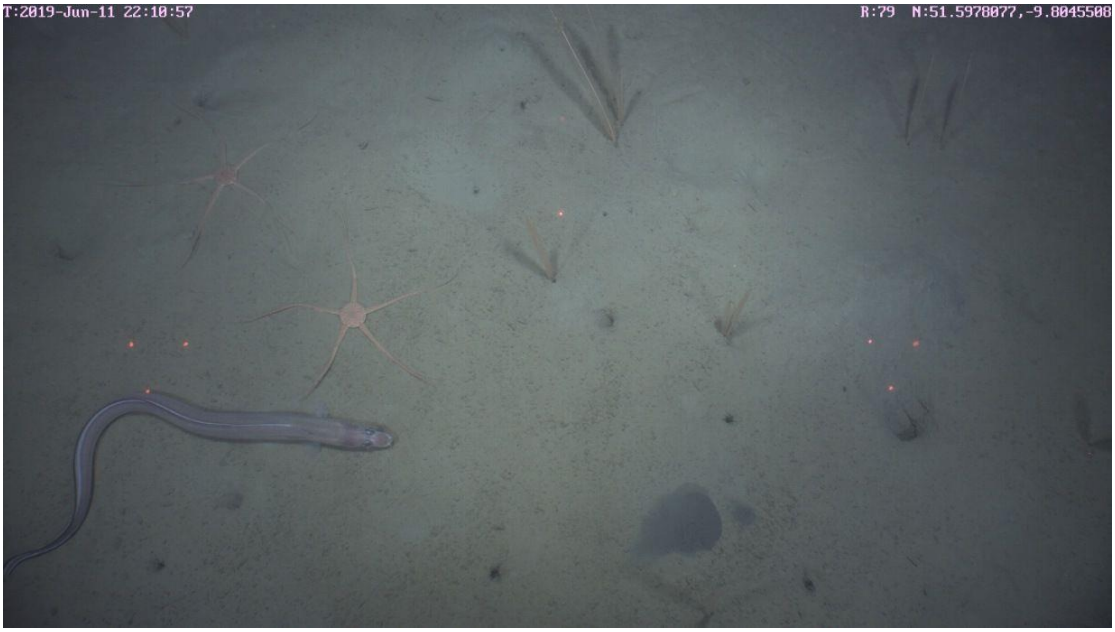


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## Abstract

This report provides the main results of the tenth underwater television survey of the various *Nephrops* patches in Functional Unit 19. The survey was multi-disciplinary in nature collecting UWTV, multi-beam and other ecosystem data. In 2019 a total 44 UWTV stations were successfully completed. The mean density estimates varied considerably across the different patches. The 2019 raised abundance estimate was a 220% increase from the 2018 estimate and at 386 million burrows is below the MSY $B_{trigger}$ (430 million). Using the 2019 estimate of abundance and updated stock data implies catch in 2020 that correspond to the F ranges in the EU multi annual plan for Western Waters are between 749 and 839 tonnes (assuming that discard rates and fishery selection patterns do not change from the average of 2016–2018). Two species of sea pen were observed; *Virgularia mirabilis* and *Pennatula phosphorea* which have been observed on previous surveys of FU19. Trawl marks were observed at 12 % of the stations surveyed.

Key words: *Nephrops norvegicus,* stock assessment, geostatistics, underwater television (UWTV), benthos, CTD.

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## Introduction

*Nephrops norvegicus* are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas were the sediment is suitable for them to construct their burrows. The *Nephrops* fishery in ICES sub-area 7 is extremely valuable with Irish landings in 2018 worth around €56 million at first sale. The Celtic Sea area (Functional Units 19-22) supports a large multi-national targeted *Nephrops* fishery mainly using otter trawls and yielding landings in the region of ~5,000 t annually. Over the last decade reported landings from FU19 have been at around 580 t (ICES, 2019). The 2018 landings of around 210 t are estimated to be worth €1.5 m at first sale. The *Nephrops* fishery in FU19 occurs on several spatially discrete patches of suitable habitat which are spread out over a large area (Figure 1).

*Nephrops* spend a great deal of time in their burrows and their emergence behaviour is influenced by many factors; time of year, light intensity and tidal strength. Underwater television surveys and assessment methodologies have been developed to provide a fishery independent estimate of stock size, exploitation status and catch advice for several *Nephrops* stocks around Ireland (ICES, 2009, 2011).

The 2019 survey was multi-disciplinary in nature and also covered TV stations in FU17 and FU22 the results of which are presented elsewhere (Doyle *et. al*., 2019, Aristegui et al., 2019). The specific objectives of 2019 survey are listed below:

1. To obtain 2019 quality assured estimates of *Nephrops* burrow densities from several of the discrete mud patches of *Nephrops* ground in FU19.
2. To compare burrow density estimates with those made by previous surveys.
3. To collect ancillary information from the UWTV footage collected at each station such as the occurrence of sea-pens, other macro benthos and fish species and trawl marks on the sea bed.
4. To collect oceanographic data using a sledge mounted CTD.

This report details the final UWTV results of the 2019 FU19 survey and also documents other data collected during the survey. Operational survey details are available in the form of a survey narrative from the scientists in charge (JD). The 2019 abundances are used to generate catch scenarios for 2020 in line with the recommendations and procedures outlined in the stock annex for FU19 (ICES, 2019).

## Material and methods

The spatial extent of the *Nephrops* grounds in FU19 has been defined using 2006-2014 integrated VMS-logbook data using the methods described in Gerritsen and Lordan (2011) along with using multi-beam backscatter data from seabed mapping programmes (ICES, 2014). The discrete patches have been named as: Bantry Bay, Galley Ground 1-4, Cork Channels and Helvick 1 & 2 (Figure 1). The area of each ground polygon is shown in Table 1 as defined by WKCELT (ICES, 2015). *Nephrops* also occur outside these defined polygons in areas such as Kenmare Bay which was surveyed for the fifth time this year (2 stations completed). Two new stations in

Dunmanus Bay were completed for the first time to map this *Nephrops* patch where positions for clear tracks were provided by fishing industry. These stations are not included in the 2019 final estimate of abundance for FU19 as these are considered exploratory.

In 2019 UWTV stations (except Dunmanus Bay) were randomly picked within each patch using the "spsample" function from the "R" library "sp" (Pebesma & Bivand, 2005) of "R" (R Core Team, 2017). The planned stations are shown in Figure 2. Previously stations were randomly chosen using the "Create Random Points" tool in ArcToolbox of ArcGIS10. The sampling effort, i.e. the numbers of stations, on each ground were determined relative to the spatial extent of each patch, as in previous years.

The 2019 FU19 survey took place on RV. Celtic Voyager from 9th to 20th June. Surveys in other years were generally between June to September (Figure 2).
In 2019 image data was collected by a custom built camera system recording High Definition still image data at 12 frames per second with a camera angle of 75 (°). The digital images were stored on a server and were reviewed onboard through an inhouse developed Image annotation R Shiny app (Aristegui, 2019). This application allows each reviewer to annotate burrows for each randomly assigned station in an efficient manner. The survey process is now paperless.

The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and used in all other grounds surveyed by Ireland. These can be summarised as follows: At each station the UWTV sledge was deployed and once stable on the seabed a 10 minute tow was recorded. Time referenced high definition image data was collected with a field of view or 'FOV' of 1.01 m. Vessel position (DGPS) and position of sledge using a USBL transponder were recorded every 3 seconds. The navigational data were quality controlled using an "R" script developed by the Marine Institute (ICES, 2009b). In 2019 the USBL navigational data was used to calculate distance over ground for all of the stations. Station depths ranged from 24 metres on Helvick grounds to 107 metres on the Galley Grounds.

In line with recommendations of the Study Group on *Nephrops* Surveys (SGNEPS; ICES, 2012) all scientists were trained/re-familiarised using 2019 image data as training material prior to recounting in the laboratory ashore. (ICES, 2009b). There is no FU19 specific reference footage available yet in standard or high definition format. Once this process had been undertaken, all recounts were conducted by two trained "burrow identifying" scientists independent of each other on board the research vessel during the survey.

During the survey review process the numbers of *Nephrops* burrows systems (multiple burrows in close proximity to one another, which appear to be part of a single system and were counted once) for each one-minute interval. In addition *Nephrops* activity in and out of burrows was also counted by each scientist for the full UWTV station. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009b).

Presence / absence notes were also recorded on the occurrence of trawl marks, fish species and other species. Presence / absence of sea-pen species were also recorded to fulfil an OSPAR Special Request (ICES 2011).

Finally, if there was any time during each minute where counting was not possible, due to sediment clouds or other reasons, this was recorded and removed from the distance over ground calculations. The "R" quality control tool allowed for the data quality of navigation, speed, visual clarity and consistency in counts to be checked (an example is given in Figure 3).

In 2019 the survey count data was screened to check for any unusual discrepancies using Lin's Concordance Correlation Coefficient (CCC) with a threshold of 0.5. Lin's CCC (Lin, 1989) measures the ability of counters to exactly reproduce each other's counts on a scale of 1 to –1 where 1 is perfect concordance (i.e. a pairwise plot will have all points lying along the 1:1 line. A value of –1 would be generated by all points lying on the –1:1 line and a value of 0 indicates no correspondence at all. Lin's CCC quality control plots of count data for stations 276, 277 and 279 are shown in Figure 4. When the count data fell below the threshold of 0.5 a third review was carried out. The paired count data that passed the Lin's CCC threshold was used in the analysis. When the paired counts did not pass the threshold an average of the three reviewers was deemed appropriate to use in the analysis.

Mean density was calculated by dividing the total number of burrow systems by the survey area observed. The USBL positional data was used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated by extrapolation at 1.01 m assuming that the sledge was flat on the seabed (i.e. no sinking). Occasionally the lasers were not visible at the bottom of the screen due to sinking in very soft mud, the impact of this is a minor under estimate of densities at stations where this occurred.

For each UWTV station a temperature and depth profile was logged for the duration of each tow using a sled mounted and calibrated Seabird SBE39plus. This data will be processed at a later stage inhouse.

A global mean density and summary statistics (number of stations, standard deviation, standard error, 95% confidence intervals and CV) were estimated for all stations. Mean Density was multiplied by the total area given in Table 1 to estimate the raised abundance estimate along with confidence intervals. All analysis was carried out using "R" (R Core Team, 2017). The same approach has been used since 2015. Prior to 2013 some other adjustments were made to account for incomplete survey coverage. Details of these are given in previous survey reports (Lordan, *et al.*, 2013).

## Results

The summary statistics for the various discrete *Nephrops* patches within FU19 are given in Table 2. Figure 5 shows the variability in density between minutes and operators (counters) for each station. These show that the burrow estimates are fairly consistent between minutes and counters. The 2019 mean adjusted[1] burrow density estimates vary considerably, from the lowest observed at Helvick 2 of 0.0 (burrows/m²) to the highest of 0.66 (burrows/m²) at Galley Grounds 2. The mean density for most patches showed an increase compared with 2018. Bubble plots of densities over the time-series by discrete patch show variability across the grounds and years (Figure 6). The adjusted burrow densities for each *Nephrops* patch from 2006 to 2019 are shown in Figure 7 as a violin and box plot. For the most grounds the observed densities were higher in 2019 compared to the previous year.

The adjusted burrow densities for the combined FU19 grounds from 2006 to 2019 are shown in Figure 8. The 2019 mean density of 0.20 burrows/$m^2$ was 220% higher than 2018, and is the second lowest observed in the time-series.

The time series of summary statistics for FU19 are given in Table 3. The 2019 raised abundance estimate of 386 million burrows is a 220% increase from the 2018 estimate (Figure 9), and just below the MSY $B_{trigger}$ reference point (430 million). The CV or RSE (relative standard error) for the 2019 survey was 17% which is below the upper limit of 20% recommended by SGNEPS (ICES, 2012).

Sea-pen distribution across the FU19 *Nephrops* grounds is mapped in Figure 9. Two species; *Virgularia mirabilis* and *Pennatula phosphorea* were identified from the image data. Trawl marks were noted at 12% of the stations surveyed.

The UWTV abundance data together with data from the fishery; landings, discards and removals in number are used to calculate the harvest rate in 2018 of 6.2%. The mean weight in the landings and the discards and the proportions of removal retained are also shown (Table 4). The basis to the catch scenarios is given in Table 5.

The catch and landings scenarios at various different fishing mortalities were calculated in line with the stock annex of the Report of the Working Group on Celtic Seas Ecoregion (ICES, 2019) using the 2019 survey abundance (Table 6). The latest estimate of stock abundance is below the MSY $B_{trigger}$ (value 430 million). The ICES MSY approach states that under such conditions the $F_{MSY}$ harvest rate (9.3% for FU 19 Norway lobster) should be reduced by multiplying it by the ratio of the current abundance to MSY $B_{trigger.}$ This corresponds to a harvest rate of [9.3 × (386/430)] = 8.4% for the catch advice in 2020. Fishing at the EU MAP F ranges in 2020 would result in catches between 749 and 839 tonnes assuming that discard rates and fishery selection patterns do not change from the average of 2016–2018.

[1] Note the "adjusted" density estimates in this report are adjusted by dividing by 1.3 to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).

## Discussion

The time series of UWTV survey information is developing for this Functional Unit. Several discrete mud patches with fished *Nephrops* populations have been identified and the survey coverage and precision since 2011 has been reasonable. It is clear that there are consistent differences in density in the different patches but most patches seem to vary annually in a similar way. Scientific knowledge of the spatial distribution of the *Nephrops* habitat in this area is developing thanks to new multi-beam data (www.infomar.ie), more extensive VMS data and information from the fishing industry particularly for inshore areas.

*Nephrops* fisheries in this area have been covered under the landings obligation since 2016 with several exemptions. Irish discard survival experiments indicate that the trawl discard survival may be around 64% (BIM, 2017). As a result, an exemption from the landings obligation based on high survivability has been granted by the European Commission. Discard rates for this FU are estimated to be relatively high at approximately 50% by number and 25% by weight in the last three years. The provision of catch advice and scenarios for 2020 based on the EU MAP (EU, 2019) F ranges assumes that discarding will continue at the average rate estimated between 2016 and 2018.

The imposition of the landings obligation on *Nephrops* fisheries since 2016 should result in changes in selectivity in the fisheries with high discard rates like FU19. This is not taken into account in any of the catch advice because it is not possible to predict exactly what might happen. The main message is that any improvements in selectivity in the fishery and reductions in discards will result in increased mean weight in the catches. This should in turn reduce overall mortality on the stocks and allow for catch increases in the future.

An important objective of this UWTV survey is to collect ancillary information. The occurrence of trawl marks on the footage is notable for two reasons. Firstly, it makes identification of *Nephrops* burrows more difficult as the trawl marks remove some signature features making accurate burrow identification more difficult. Secondly, only occupied *Nephrops* burrows will persist in heavily trawled grounds and it is assumed that each burrow is occupied by one individual *Nephrops* (ICES 2008).

Monitoring the occurrence and frequency of sea-pens observed on these *Nephrops* patches is important in the context of OSPAR's designation of sea-pen and burrowing megafauna communities as threatened. Two sea-pen species: *Virgularia mirabilis and Pennatula phosphorea* were seen in 2019. These have been observed on previous surveys of FU19. Monitoring *Nephrops* stocks and the benthic habitat is also important in the context of the MFSD indicators (e.g. sea floor integrity).

The main objectives of the survey were successfully met for the tenth time. The UWTV image data quality was excellent and in 2019 and all of the *Nephrops* patches within FU19 were successfully surveyed. The multi-disciplinary nature of the survey

means that the information collected is highly relevant for a number of research and advisory applications.

## Acknowledgments

We would like to express our sincere thanks and gratitude to Phillip Baugh (Master) and crew of the RV. Celtic Voyager. Thanks to the onboard P&O technical staff Lukasz Pawlikowski and Tim O'Sullivan who maintained the UWTV system throughout the survey. Thanks to Aodhán Fitzgerald, Rosemarie Butler (RVOPs) and Rob Bunn and Dave Tully (FEAS) at the Marine Institute for organising survey logistics, and also Gordon Furey and Damian Crean (P&O Maritime) for shore side support.

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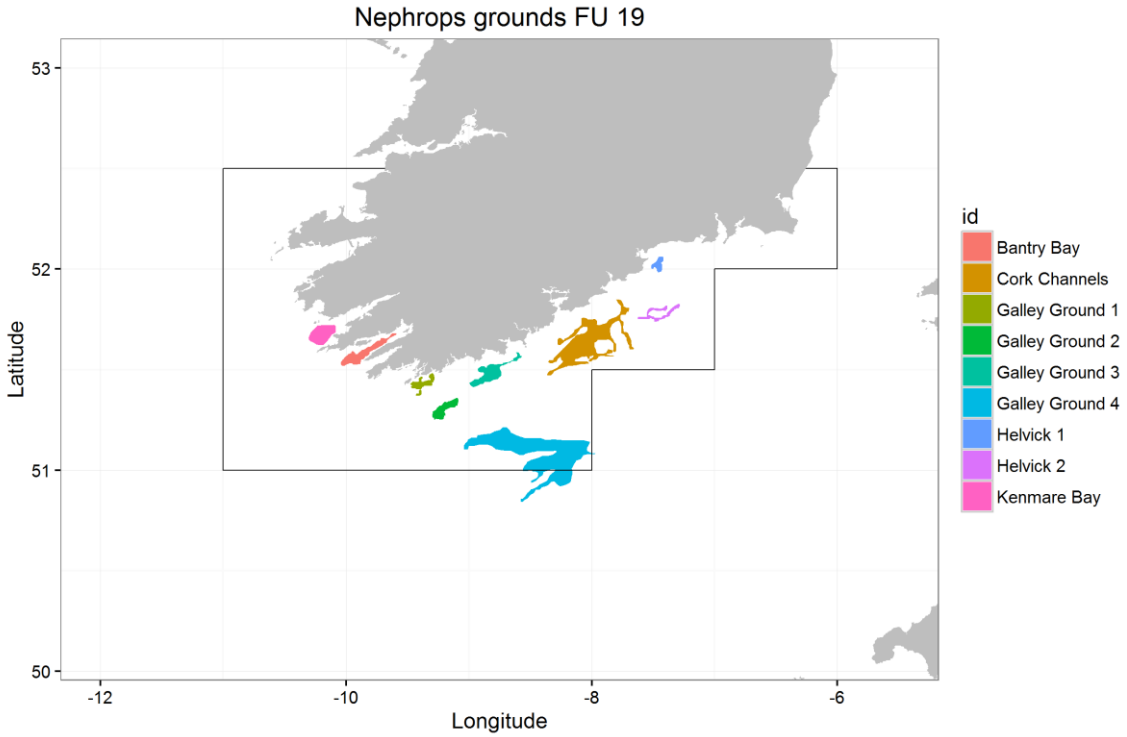


**Figure 1**: FU19 grounds: Individual *Nephrops* ground area polygons in Functional Unit 19.

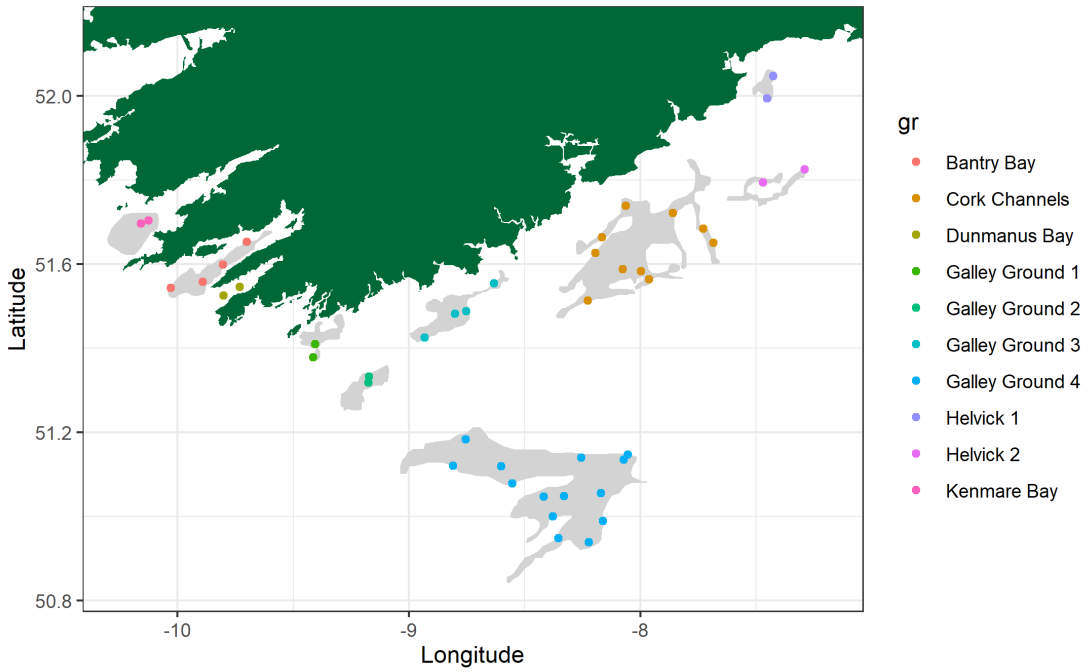


**Figure 2**: FU19 grounds: Stations completed on the 2019 *Nephrops* UWTV survey.

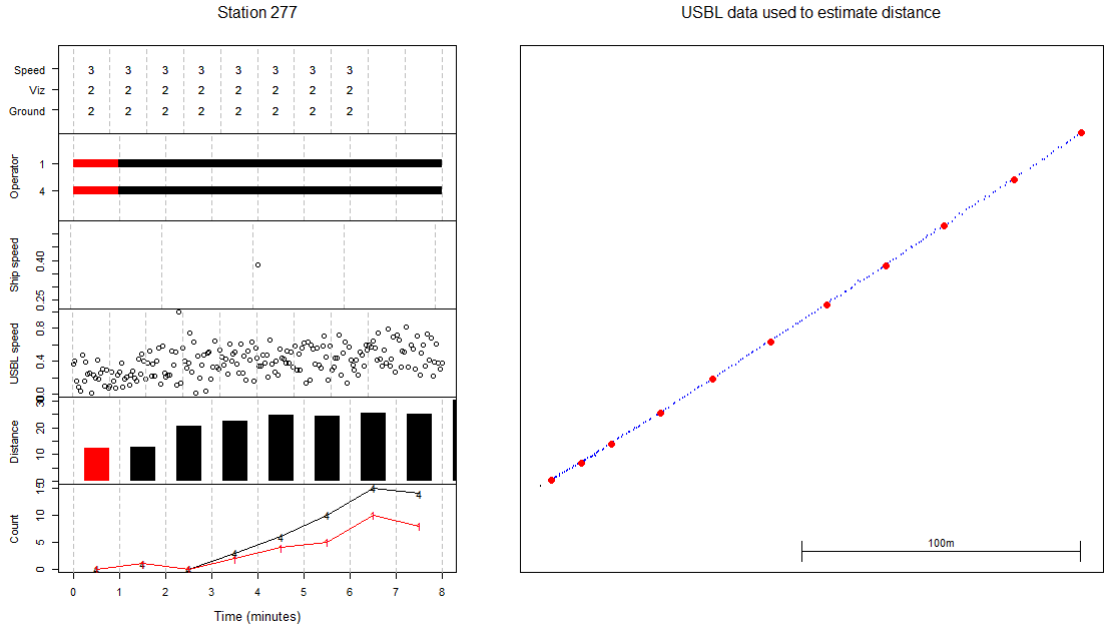


**Figure 3**: FU19 grounds: R - tool quality control plot for station 277 of the 2018 UWTV survey.

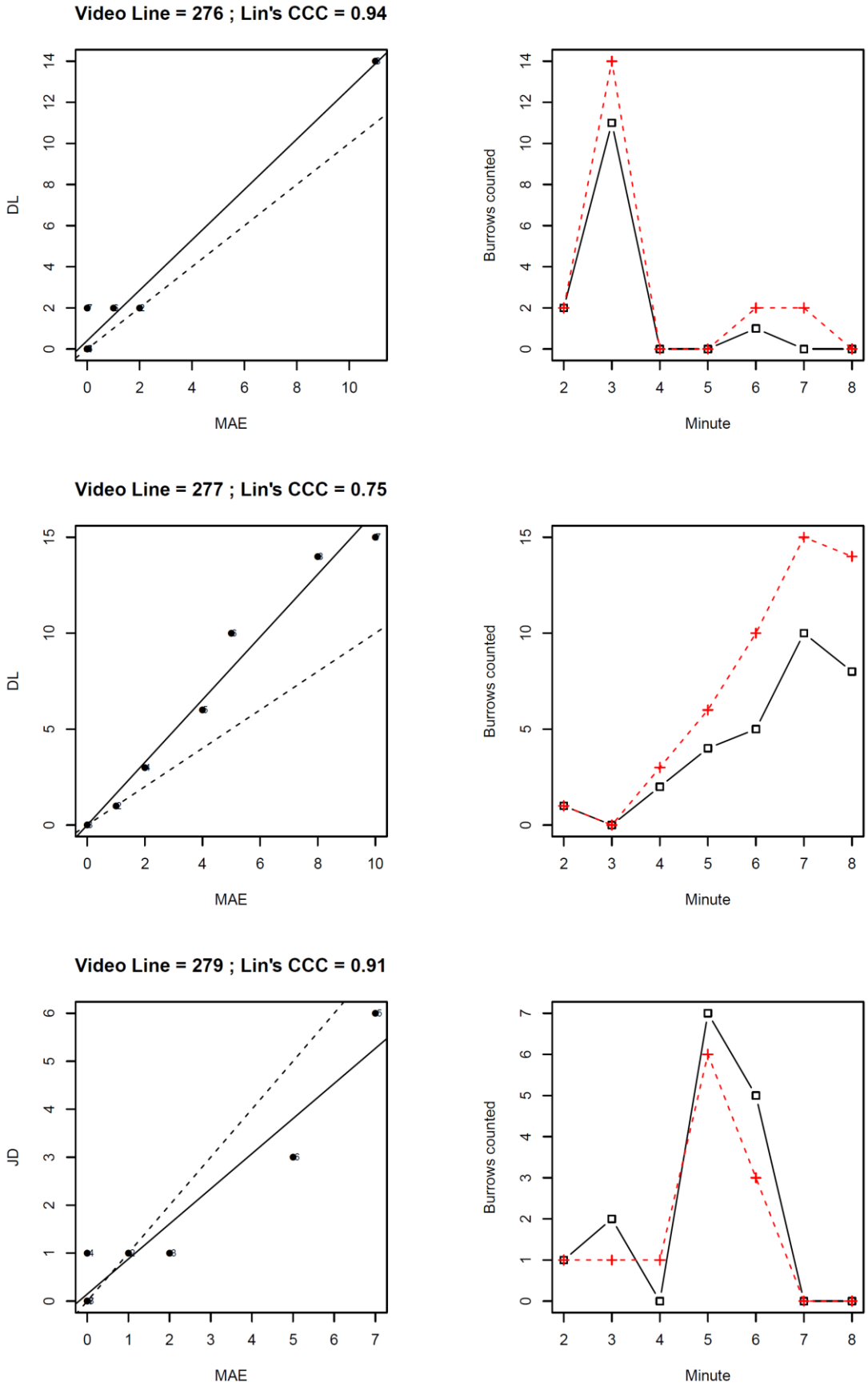


**Figure 4**: FU19 grounds: Lin's CCC quality control plot of count data for stations 276, 277 and 279 of the 2019 survey.

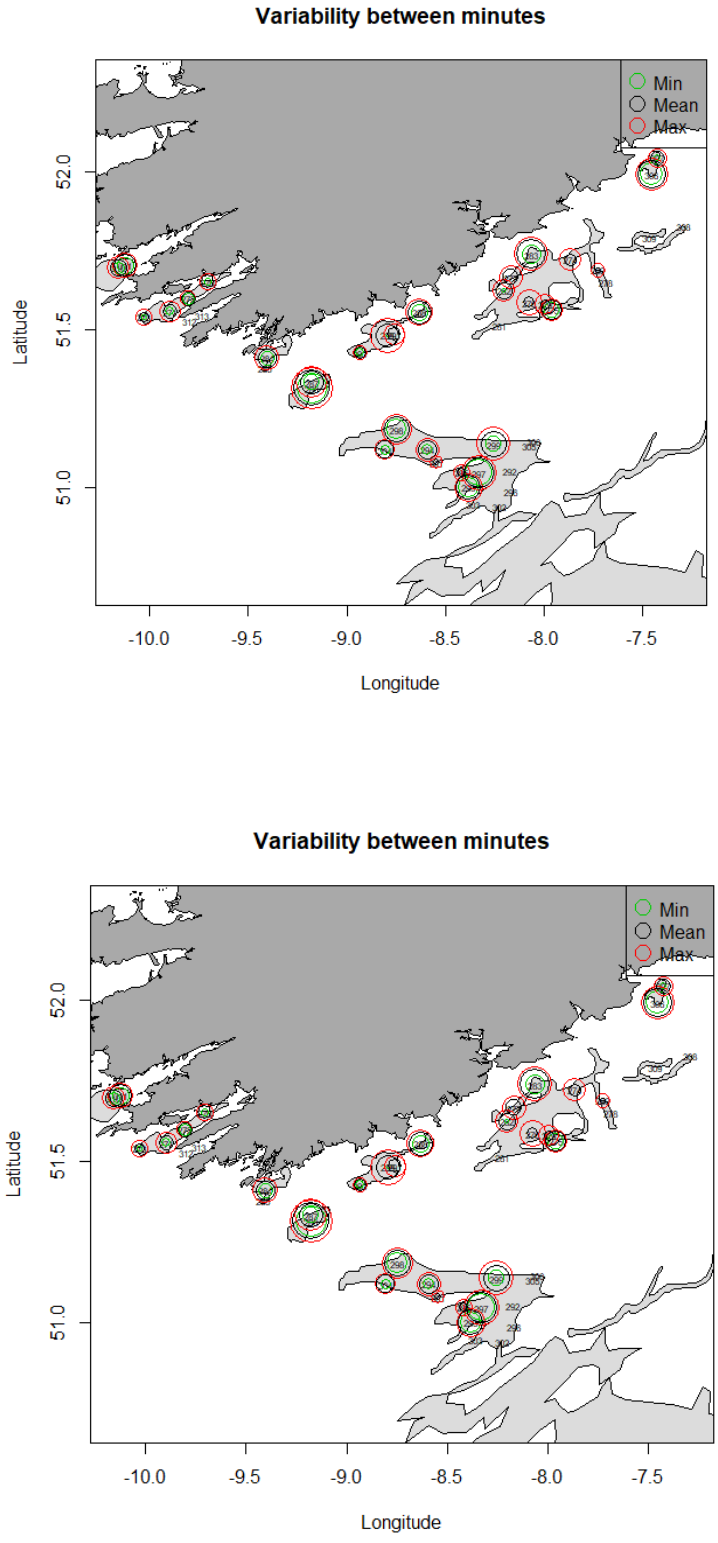


**Figure 5:** FU19 grounds: Plot of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2019.

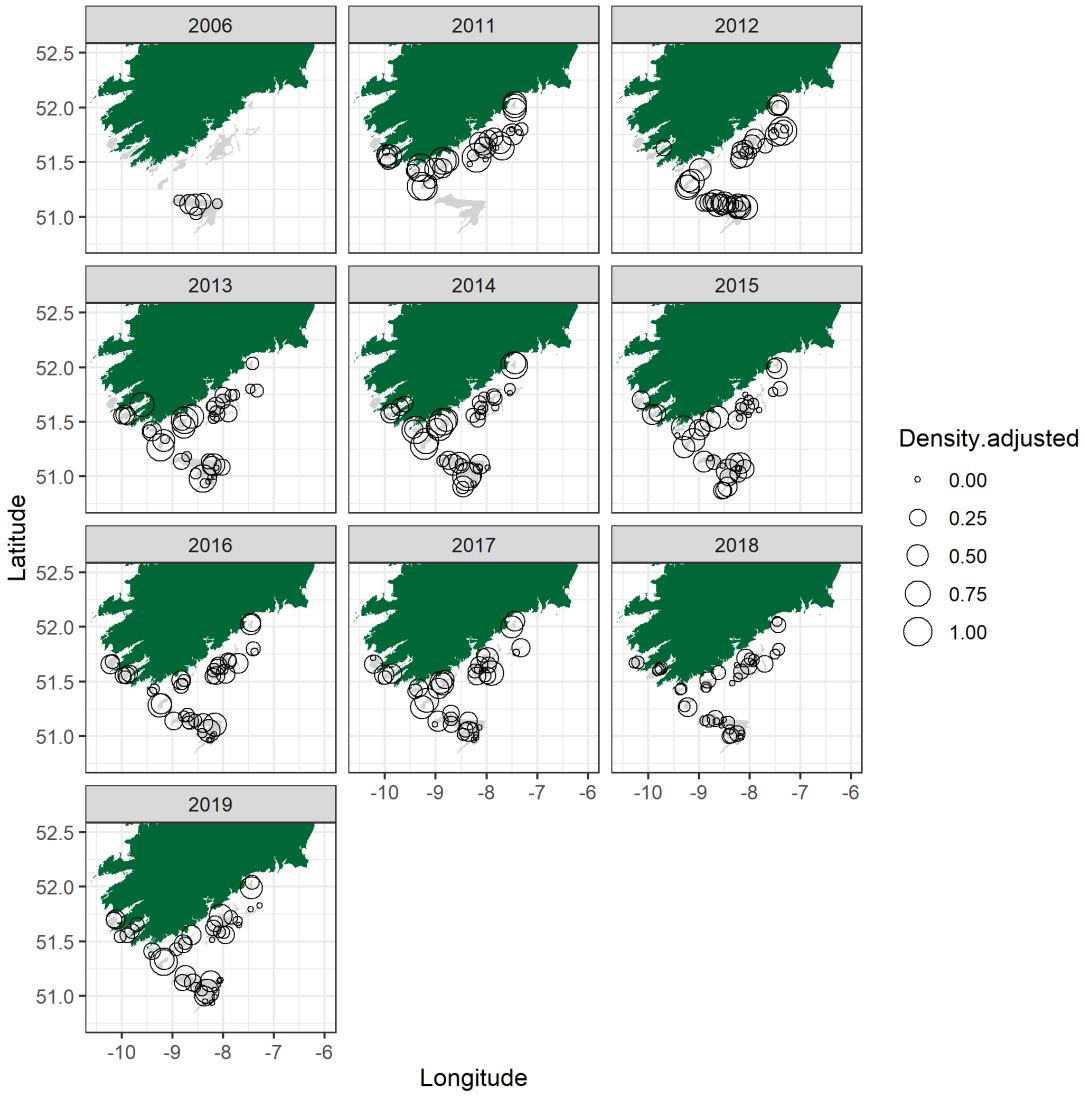


**Figure 6:** FU19 grounds: Bubble plot of the adjusted density (burrows/m²) from 2006 to 2019.

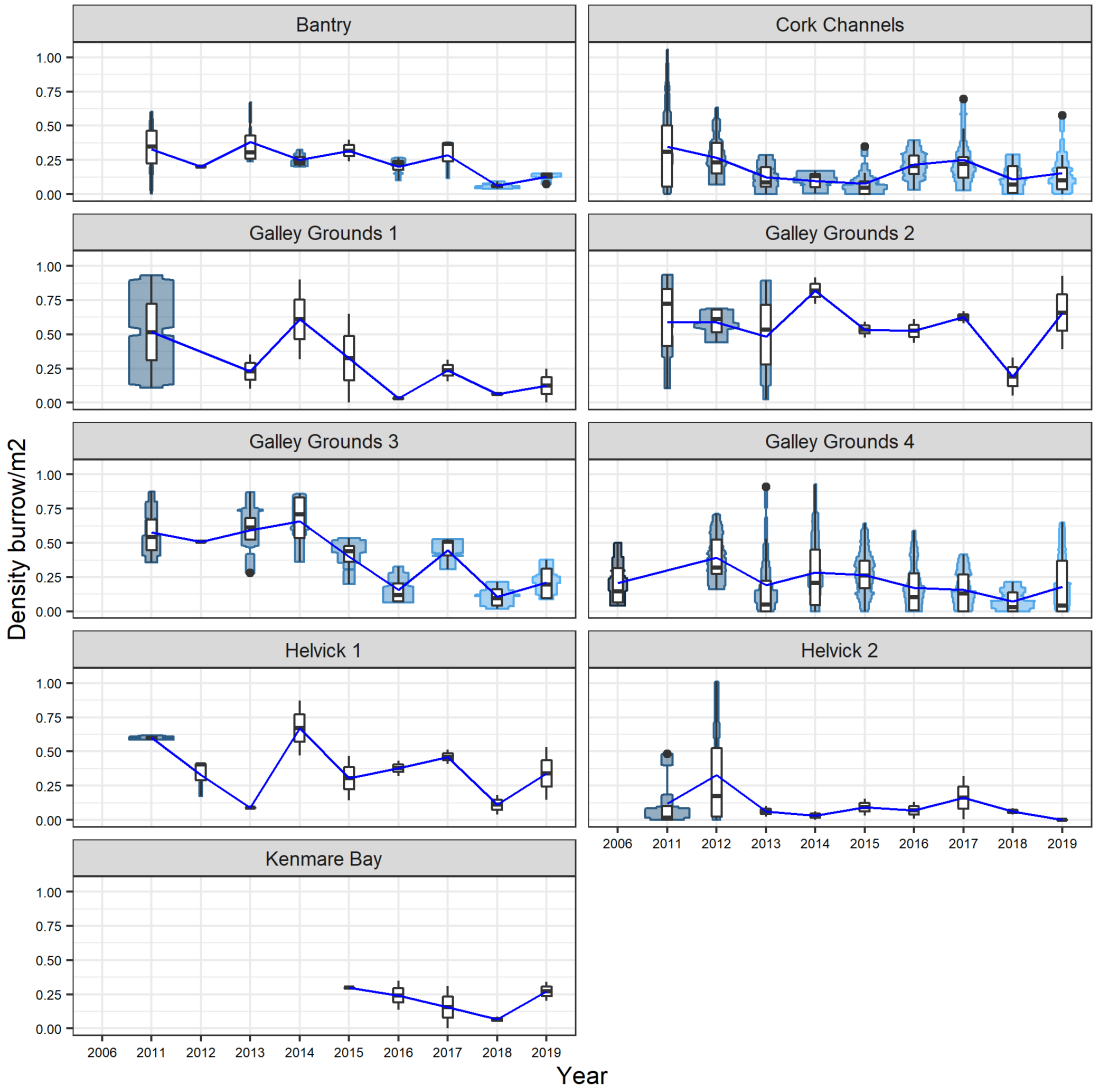


**Figure 7**: FU19 grounds: Violin and box plots of adjusted burrow density distributions by year for 2006-2019 for each ground. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. No TV survey from 2007 – 2010.

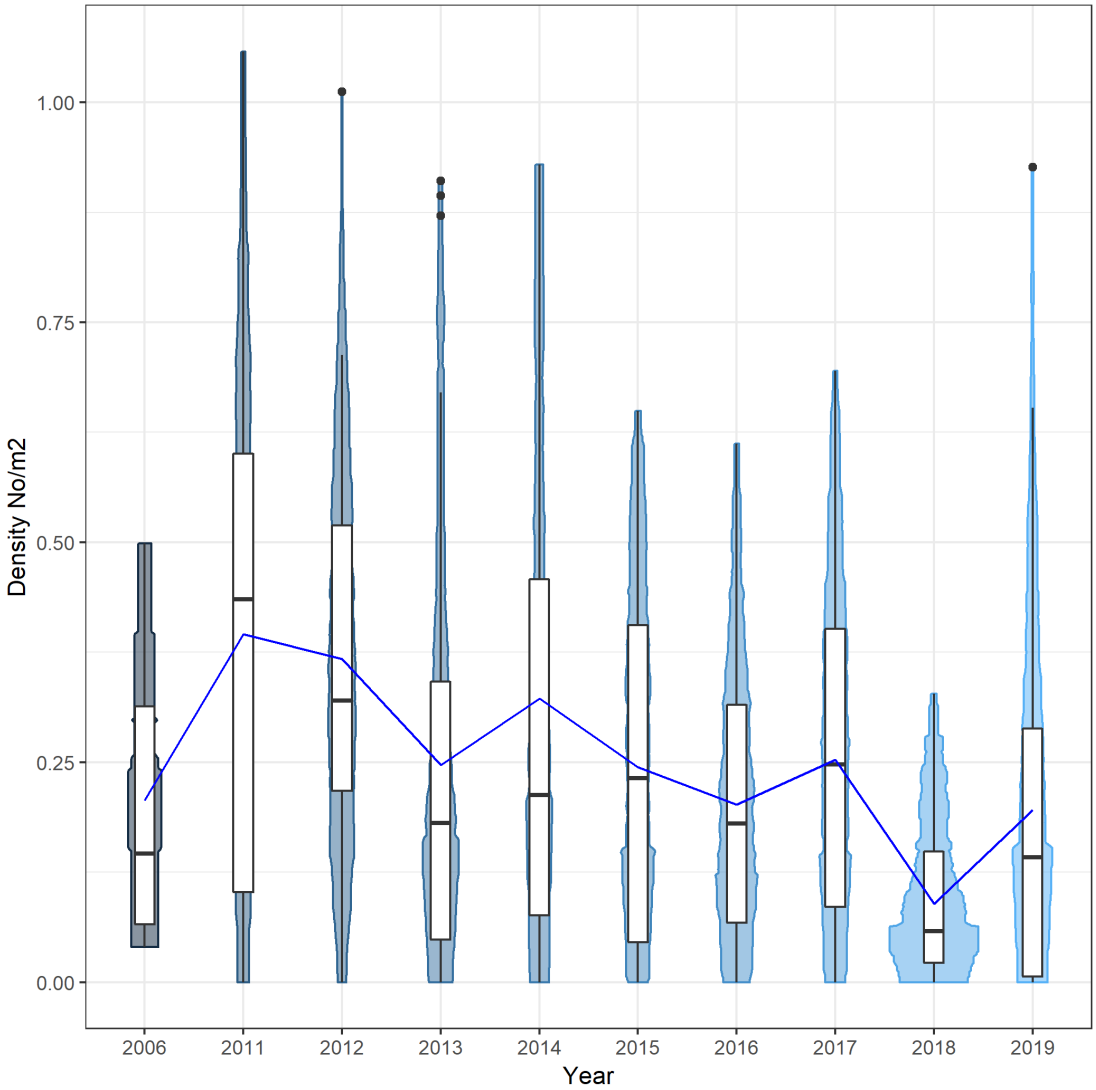


**Figure 8**: FU19 grounds: Combined violin and box plot of adjusted burrow density distributions by year for 2006-2019. The blue line indicates the mean density over time. The horizontal black lines represent medians, white boxes the inter quartile ranges, the black vertical lines the range and the black dots are outliers. No TV survey from 2007 – 2010.

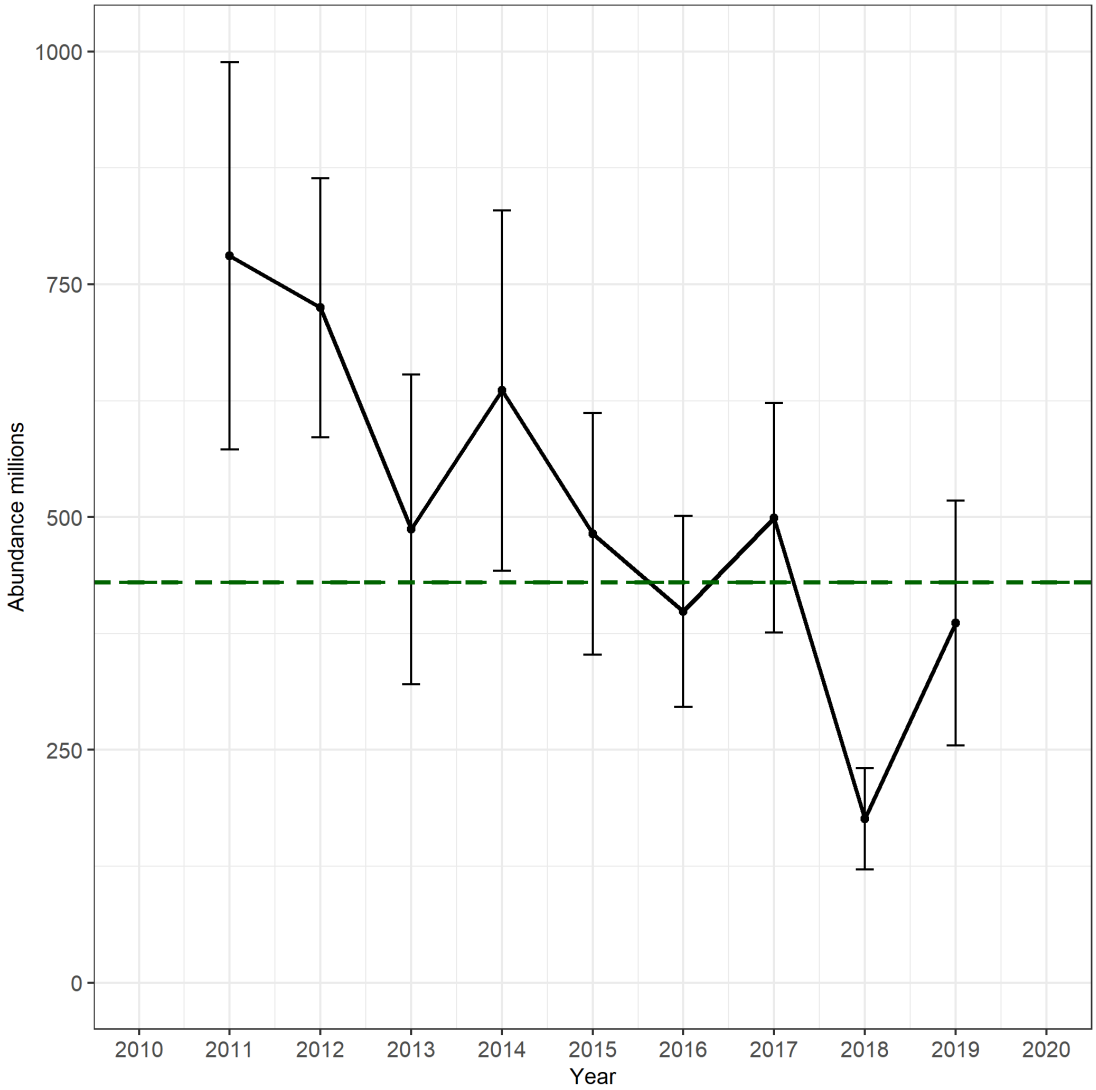


**Figure 9:** FU19 grounds: Time series of raised abundance estimates (in millions of burrows) for FU19. No survey data from 2007 to 2010. The error bars indicate the 95% confidence intervals and and $B_{trigger}$ is dashed green line.

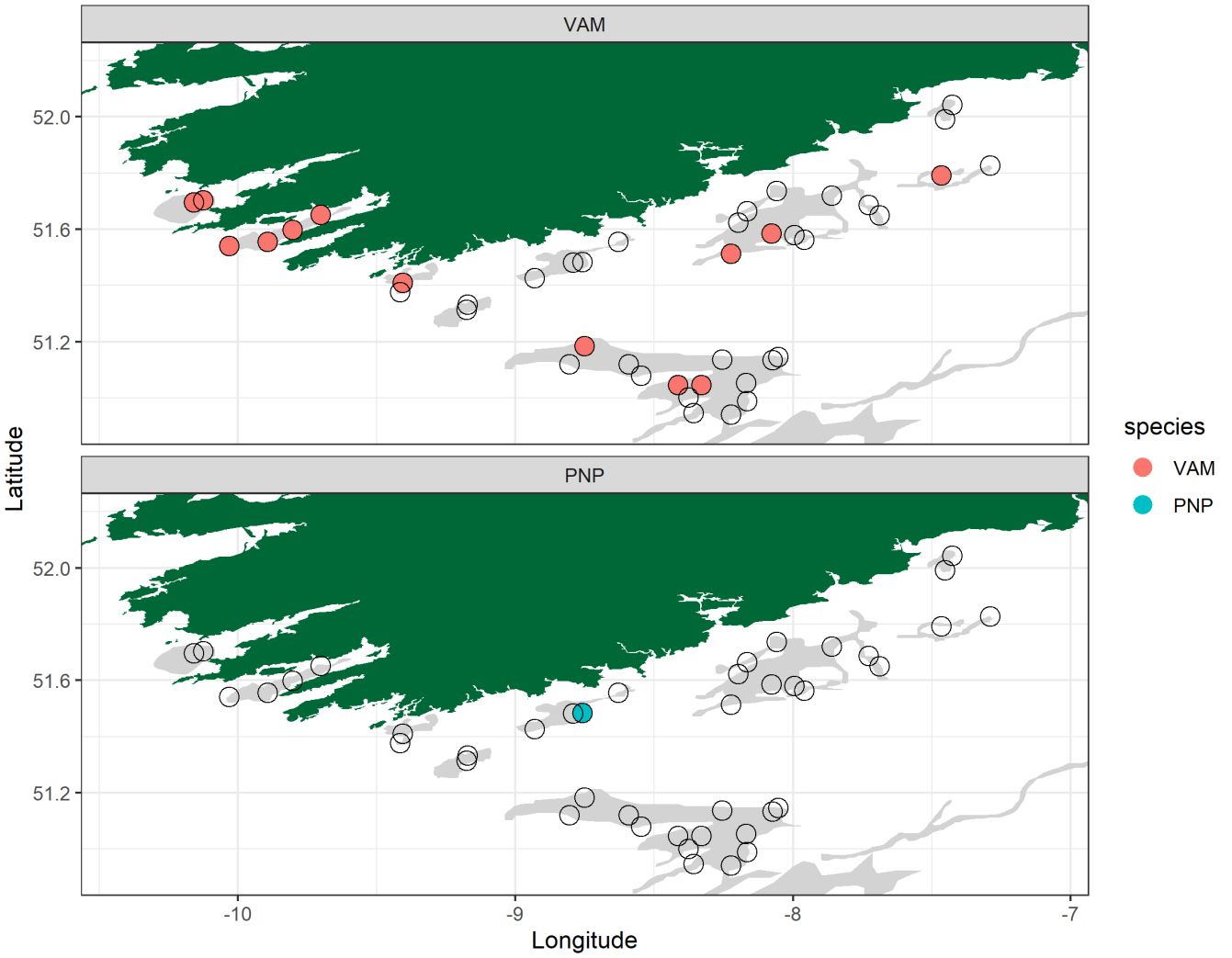


**Figure 10:** FU19 grounds: 2019 stations where *Virgularia mirabilis* (VAM ) top panel and *Pennatula phosphorea* (PNP) bottom panel were identified and noted as present or absent. Closed circles indicated presence and open circles denotes TV stations with no sea-pen observations.

**Table 1:** FU19 grounds: Area calculations for the various *Nephrops* grounds in FU19 (ICES, 2014).

| Ground Name | Area (km²) |
|---|---|
| Bantry | 121.52 |
| Cork Channels | 562.01 |
| Galley Grounds 1 | 60.86 |
| Galley Grounds 2 | 76.74 |
| Galley Grounds 3 | 133.94 |
| Galley Grounds 4 | 925.10 |
| Helvick 1 | 33.09 |
| Helvick 2 | 59.52 |
| Total | 1,972.78 |

**Table 2:** FU19 grounds: Detailed summary statistics for the various *Nephrops* patches in FU19 over the time series. (N = number of stations, Mean Density ($N/m^2$) is adjusted for the bias correction factor, sd, se and ci are the standard deviation, standard error and 95% confidence intervals on the mean density).

| Year | Ground | N | Mean Density ($N/m^2$) | sd | se | ci |
|---|---|---|---|---|---|---|
| 2006 | Galley Grounds 4 | 6 | 0.21 | 0.18 | 0.08 | 0.19 |
| 2011 | Bantry | 5 | 0.33 | 0.23 | 0.1 | 0.28 |
| 2011 | Cork Channels | 12 | 0.35 | 0.32 | 0.09 | 0.2 |
| 2011 | Galley Grounds 1 | 3 | 0.52 | 0.41 | 0.24 | 1.02 |
| 2011 | Galley Grounds 2 | 3 | 0.59 | 0.43 | 0.25 | 1.07 |
| 2011 | Galley Grounds 3 | 4 | 0.58 | 0.22 | 0.11 | 0.35 |
| 2011 | Helvick 1 | 3 | 0.6 | 0.01 | 0.01 | 0.04 |
| 2011 | Helvick 2 | 5 | 0.12 | 0.21 | 0.09 | 0.26 |
| 2012 | Bantry | 1 | 0.2 | NA | NA | NA |
| 2012 | Cork Channels | 9 | 0.27 | 0.17 | 0.06 | 0.13 |
| 2012 | Galley Grounds 2 | 4 | 0.59 | 0.12 | 0.06 | 0.19 |
| 2012 | Galley Grounds 3 | 1 | 0.51 | NA | NA | NA |
| 2012 | Galley Grounds 4 | 16 | 0.39 | 0.16 | 0.04 | 0.09 |
| 2012 | Helvick 1 | 3 | 0.33 | 0.13 | 0.08 | 0.33 |
| 2012 | Helvick 2 | 6 | 0.33 | 0.41 | 0.17 | 0.43 |
| 2013 | Bantry | 4 | 0.38 | 0.2 | 0.1 | 0.31 |
| 2013 | Cork Channels | 11 | 0.12 | 0.1 | 0.03 | 0.07 |
| 2013 | Galley Grounds 1 | 2 | 0.23 | 0.18 | 0.13 | 1.59 |
| 2013 | Galley Grounds 2 | 3 | 0.48 | 0.44 | 0.25 | 1.09 |
| 2013 | Galley Grounds 3 | 4 | 0.59 | 0.24 | 0.12 | 0.38 |
| 2013 | Galley Grounds 4 | 13 | 0.19 | 0.27 | 0.07 | 0.16 |
| 2013 | Helvick 1 | 1 | 0.09 | NA | NA | NA |
| 2013 | Helvick 2 | 2 | 0.06 | 0.05 | 0.04 | 0.48 |
| 2014 | Bantry | 4 | 0.25 | 0.05 | 0.03 | 0.09 |
| 2014 | Cork Channels | 10 | 0.1 | 0.06 | 0.02 | 0.04 |
| 2014 | Galley Grounds 1 | 2 | 0.61 | 0.41 | 0.29 | 3.69 |
| 2014 | Galley Grounds 2 | 2 | 0.82 | 0.14 | 0.1 | 1.23 |
| 2014 | Galley Grounds 3 | 4 | 0.66 | 0.23 | 0.12 | 0.37 |
| 2014 | Galley Grounds 4 | 14 | 0.29 | 0.29 | 0.08 | 0.17 |
| 2014 | Helvick 1 | 2 | 0.67 | 0.28 | 0.2 | 2.53 |
| 2014 | Helvick 2 | 2 | 0.03 | 0.04 | 0.03 | 0.39 |
| 2015 | Bantry | 2 | 0.32 | 0.11 | 0.08 | 1.02 |
| 2015 | Cork Channels | 10 | 0.08 | 0.11 | 0.03 | 0.08 |
| 2015 | Galley Grounds 1 | 2 | 0.32 | 0.46 | 0.32 | 4.12 |
| 2015 | Galley Grounds 2 | 2 | 0.53 | 0.08 | 0.06 | 0.74 |

**Table 2 (cont.):** FU19 grounds: Detailed summary statistics for the various *Nephrops* patches in FU19 over the time series. (N = number of stations, Mean Density (N/m²) is adjusted for the bias correction factor, sd, se and ci are the standard deviation, standard error and 95% confidence intervals on the mean density).

| Year | Ground | N | Mean Density (N/m²) | sd | se | ci |
|---|---|---|---|---|---|---|
| 2015 | Galley Grounds 3 | 4 | 0.4 | 0.14 | 0.07 | 0.23 |
| 2015 | Galley Grounds 4 | 14 | 0.27 | 0.19 | 0.05 | 0.11 |
| 2015 | Helvick 1 | 2 | 0.3 | 0.23 | 0.16 | 2.08 |
| 2015 | Helvick 2 | 2 | 0.09 | 0.09 | 0.06 | 0.79 |
| 2015 | Kenmare Bay | 1 | 0.3 | NA | NA | NA |
| 2016 | Bantry | 4 | 0.2 | 0.07 | 0.04 | 0.12 |
| 2016 | Cork Channels | 10 | 0.21 | 0.11 | 0.03 | 0.08 |
| 2016 | Galley Grounds 1 | 2 | 0.03 | 0.01 | 0.01 | 0.08 |
| 2016 | Galley Grounds 2 | 2 | 0.53 | 0.12 | 0.09 | 1.11 |
| 2016 | Galley Grounds 3 | 4 | 0.16 | 0.12 | 0.06 | 0.19 |
| 2016 | Galley Grounds 4 | 14 | 0.17 | 0.2 | 0.05 | 0.12 |
| 2016 | Helvick 1 | 2 | 0.38 | 0.08 | 0.06 | 0.7 |
| 2016 | Helvick 2 | 2 | 0.07 | 0.09 | 0.06 | 0.81 |
| 2016 | Kenmare Bay | 2 | 0.24 | 0.15 | 0.11 | 1.33 |
| 2017 | Bantry | 3 | 0.29 | 0.15 | 0.09 | 0.37 |
| 2017 | Cork Channels | 10 | 0.25 | 0.20 | 0.06 | 0.14 |
| 2017 | Galley Grounds 1 | 2 | 0.24 | 0.11 | 0.08 | 1.00 |
| 2017 | Galley Grounds 2 | 2 | 0.63 | 0.06 | 0.04 | 0.55 |
| 2017 | Galley Grounds 3 | 3 | 0.45 | 0.12 | 0.07 | 0.30 |
| 2017 | Galley Grounds 4 | 15 | 0.16 | 0.16 | 0.04 | 0.09 |
| 2017 | Helvick 1 | 2 | 0.46 | 0.07 | 0.05 | 0.66 |
| 2017 | Helvick 2 | 2 | 0.16 | 0.23 | 0.16 | 2.03 |
| 2017 | Kenmare Bay | 2 | 0.16 | 0.22 | 0.16 | 1.97 |
| 2018 | Bantry | 4 | 0.06 | 0.02 | 0.01 | 0.04 |
| 2018 | Cork Channels | 10 | 0.11 | 0.11 | 0.04 | 0.08 |
| 2018 | Galley Grounds 1 | 2 | 0.06 | 0.01 | 0.01 | 0.10 |
| 2018 | Galley Grounds 2 | 2 | 0.19 | 0.19 | 0.14 | 1.75 |
| 2018 | Galley Grounds 3 | 4 | 0.11 | 0.09 | 0.05 | 0.14 |
| 2018 | Galley Grounds 4 | 14 | 0.07 | 0.08 | 0.02 | 0.05 |
| 2018 | Helvick 1 | 2 | 0.11 | 0.10 | 0.07 | 0.92 |
| 2018 | Helvick 2 | 2 | 0.06 | 0.03 | 0.02 | 0.28 |
| 2018 | Kenmare Bay | 2 | 0.07 | 0.03 | 0.02 | 0.25 |
| 2019 | Bantry | 4 | 0.1280604 | 0.0372284 | 0.0186142 | 0.0592387 |
| 2019 | Cork Channels | 10 | 0.1551884 | 0.1749606 | 0.0553274 | 0.1251593 |
| 2019 | Galley Grounds 1 | 2 | 0.1235176 | 0.1746803 | 0.1235176 | 1.5694399 |
| 2019 | Galley Grounds 2 | 2 | 0.6584566 | 0.3787177 | 0.2677939 | 3.4026438 |
| 2019 | Galley Grounds 3 | 4 | 0.2127944 | 0.1424995 | 0.0712498 | 0.2267485 |
| 2019 | Galley Grounds 4 | 14 | 0.1799468 | 0.2259034 | 0.0603752 | 0.1304328 |
| 2019 | Helvick 1 | 2 | 0.3403986 | 0.274094 | 0.1938137 | 2.462637 |

**Table 2 (cont.):** FU19 grounds: Detailed summary statistics for the various *Nephrops* patches in FU19 over the time series. (N = number of stations, Mean Density (N/m²) is adjusted for the bias correction factor, sd, se and ci are the standard deviation, standard error and 95% confidence intervals on the mean density).

| Year | Ground | N | Mean Density (N/m²) | sd | se | ci |
|---|---|---|---|---|---|---|
| 2019 | Helvick 2 | 2 | 0 | 0 | 0 | 0 |
| 2019 | Kenmare Bay | 2 | 0.2702178 | 0.0977154 | 0.0690953 | 0.8779384 |
| 2019 | Dunmanus Bay* | 2 | 0 | 0 | 0 | 0 |

*exploratory stations

**Table 3:** FU19 grounds: Final of results for UWTV surveys in FU19 for 2006-2019. No UWTV survey in years 2007 to 2010.

| FU | Year | Number of stations | Mean Density adjusted (burrow /m²) | Standard Deviation | Raised abundance estimate adjusted (million burrows) | Upper 95%CI on Abundance | Lower 95%CI on Abundance | CVs |
|---|---|---|---|---|---|---|---|---|
| FU19 | 2006 | 6 | 0.21 | 0.18 | 408 | 789 | 26 | 36% |
| | 2007 | No Survey Data | | | | | | |
| | 2008 | | | | | | | |
| | 2009 | | | | | | | |
| | 2010 | | | | | | | |
| | 2011 | 35 | 0.34 | 0.26 | 665 | 842 | 488 | 13% |
| | 2012 | 40 | 0.3 | 0.18 | 594 | 708 | 480 | 9% |
| | 2013 | 40 | 0.25 | 0.26 | 487 | 653 | 320 | 17% |
| | 2014 | 40 | 0.32 | 0.31 | 636 | 829 | 442 | 15% |
| | 2015 | 39 | 0.24 | 0.2 | 482 | 612 | 352 | 13% |
| | 2016 | 42 | 0.2 | 0.17 | 399 | 501 | 296 | 13% |
| | 2017 | 41 | 0.25 | 0.20 | 499 | 622 | 376 | 12% |
| | 2018 | 42 | 0.09 | 0.09 | 176 | 230 | 122 | 15% |
| | 2019 | 42 | 0.20 | 0.21 | 386 | 517 | 255 | 17% |

**Table 4:** FU19 grounds: Inputs to catch scenarios table.

| Year | UWTV abundance estimate | 95% Confidence Interval | Landings in number | Total discards in number* | Removals in number | Harvest rate (by number) | Landings | Total discards* | Discard proportion (by number) | Dead discard proportion (by number) | Mean weight in landings | Mean weight in discards |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Millions | | | | | % | tonnes | | % | | grammes | |
| 2006 | | | 26 | 3 | 28 | | 741 | 37 | 8.9 | 6.8 | 28.3 | 14.4 |
| 2007 | | | 31 | 2 | 32 | | 957 | 26 | 4.8 | 3.6 | 31.1 | 17.0 |
| 2008 | | | 25 | 5 | 29 | | 851 | 105 | 17.7 | 13.9 | 33.7 | 19.4 |
| 2009 | | | 28 | 19 | 42 | | 868 | 269 | 39.5 | 32.8 | 30.5 | 14.5 |
| 2010 | | | 23 | 19 | 37 | | 687 | 257 | 45.1 | 38.1 | 29.6 | 13.5 |
| 2011 | 665 | 171 | 26 | 32 | 50 | 7.5 | 643 | 409 | 55.7 | 48.5 | 24.9 | 12.6 |
| 2012 | 594 | 111 | 32 | 37 | 60 | 10.1 | 849 | 473 | 53.6 | 46.4 | 26.3 | 12.7 |
| 2013 | 487 | 161 | 29 | 36 | 57 | 11.7 | 794 | 436 | 55.3 | 48.1 | 26.9 | 11.9 |
| 2014 | 636 | 188 | 16 | 11 | 25 | 3.9 | 468 | 161 | 41.1 | 34.4 | 28.6 | 14.1 |
| 2015 | 482 | 126 | 17 | 12 | 26 | 5.4 | 507 | 167 | 41.1 | 34.3 | 29.8 | 14.1 |
| 2016 | 399 | 100 | 20 | 14 | 30 | 7.5 | 590 | 193 | 40.8 | 34.1 | 29.9 | 14.2 |
| 2017 | 499 | 120 | 15 | 10 | 22 | 4.4 | 420 | 139 | 39.7 | 33.1 | 28.8 | 14.5 |
| 2018 | 176 | 53 | 8 | 4 | 11 | 6.2 | 219 | 65 | 34.8 | 28.6 | 28.2 | 15.7 |
| 2019 | 386 | 127 | 26 | 3 | | | | | | | | |

**Table 5:** FU19 grounds: The basis for the catch scenarios.

| Variable | Value | Notes |
|---|---|---|
| Stock abundance (2020) | 386 million | UWTV survey 2019 |
| Mean weight in wanted catch | 29.0 g | Average 2016–2018. |
| Mean weight in unwanted catch | 14.8 g | Average 2016–2018. |
| Unwanted catch | 38.5% | Average 2016–2018 (proportion by number). |
| Discards survival ratio | 25.0% | Proportion by number |
| Dead unwanted catch ratio | 31.9% | Average 2016–2018. |

**Table 6:** Catch advice and scenarios for 2020. Discarding assumed to continue at recent average. All weights are in tonnes.

| Basis | Total catch | Dead removals | Wanted catch | Dead unwanted catch | Surviving unwanted catch | Harvest rate*% | % advice change ** |
|---|---|---|---|---|---|---|---|
| | WC + DUC + SUC | WC +DUC | WC | DUC | SUC | for WC + DUC | |
| ICES advice basis | | | | | | | |
| MSY approach; F = EU MAP ^ : $F_{MSY}$ × (Stock Abundance 2019)/MSY $B_{trigger}$ | 839 | 788 | 636 | 152 | 51 | 8.4 | 385 |
| MAP $F_{MSY\ lower}$ × (Stock Abundance 2019)/MSY $B_{trigger}$ | 749 | 703 | 568 | 136 | 45 | 7.5 | 333 |
| MAP $F_{MSY\ upper}$ × (Stock Abundance 2019)/MSY $B_{trigger}$ | 839 | 788 | 636 | 152 | 51 | 8.4 | 385 |
| Other scenarios | | | | | | | |
| F: MAP $F_{MSY}$ | 934 | 878 | 708 | 170 | 57 | 9.3 | 440 |
| F=MAP $F_{MSY\ lower}$ | 834 | 783 | 632 | 151 | 50 | 8.3 | 382 |
| F = MAP $F_{MSY\ upper}$ *** | 934 | 878 | 708 | 170 | 57 | 9.3 | 440 |
| $F_{2018}$ | 621 | 583 | 471 | 113 | 38 | 6.2 | 259 |

^ EU multiannual plan (MAP) for Western Waters (EU, 2019).
* By number.
** Advice value for 2020 relative to advice value for 2019 (173 tonnes).
*** $F_{MSY\ upper}$ =$F_{MSY}$ for this stock.